Amendments to the Specification:

Please change the title to the following amended title:

A FEEDBACK PROCESS TO MODEL CP UTILIZATION IN MULTI-PROCESSOR PERFORMANCE MODELS

Please replace paragraph [0009] with the following amended paragraph:

[0009] In both model types, the leverage to manipulate a CP's utilization is its relative utilization during the time in which it is not waiting for a SH request to be resolved. This time is referred to herein as the CP's entry utilization χ. Then, the total utilization μ is a workload dependent and system dependent function of χ, $\mu=\mu(\chi)$ As mentioned above, μ includes CP wait times and hence is unknown, and the underlying utilization modeling problem consists in choosing χ such that $\mu=\mu(\chi)$ converges against the utilization aimed at. This utilization quantity is referred to herein as the target ~~utilization μ~~ utilization u.

Please replace paragraph [0010] with the following amended paragraph:

[0010] As mentioned before, prior art computer simulation models often ignore CP utilization completely. If, however, such prior art involves the predetermined setting of CP utilization, the most obvious approach to make μ converge ~~against μ~~ against u is the so-called regulation technique.

Please replace paragraph [0013] with the following amended paragraph:

[0013] In prior art, the algorithm to choose the entry utilization works as follows: Starting with some entry value $\chi=\chi'_1$, the simulation model runs for a while, then determines the simulated total ~~utilization μ_1~~ utilization u_1 and chooses a new value for χ to be selected for the next iteration of the simulation run: If ~~$\mu_1<\mu$~~ $u_1<u$, then $\chi'_2>\chi'_1$ is chosen and vice versa. χ' denotes the instantaneous value of χ valid for the next iteration. The quality and speed of convergence depend on the step-sizes chosen for the difference between χ'_2 and χ'_1 and on the initial value chosen for χ and may even vary with the value of the target ~~utilization μ~~ utilization u. In particular, this heuristical method is exposed to over-correct χ and hence may lead to an undesired wide oscillation of the simulated utilization ~~around μ~~ around u.

Please replace paragraph [0016] with the following amended paragraph:

[0016] In contrast to prior art algorithms as described above, the inventive algorithm uses one closed formula which was discovered within the present invention to choose the next instantaneous value χ' for the entry control quantity χ. This value applies advantageously unchanged to any target control ~~quantity μ~~ quantity u, like the before-mentioned target utilization, implies excellent ~~convergence of μ~~ convergence of u, and implicitly regards the convergence history.

Please replace paragraph [0017] with the following amended paragraph:

[0017] Thus, according to its basic aspect, a computer-program-based method for providing a feedback control for a given set of entry and target control quantities χ ~~and μ~~ and u of a system model is disclosed, the method comprising a repetition of the following steps:

a) providing a starting value χ'_1 for each of the said entry control quantities χ in the model,

b) running the model based on said starting values and obtaining a resulting actual value for each of said target control ~~quantities μ~~ quantities u,

c) using the values obtained ~~for μ~~ for u to define a new start value for χ for use in a repeated modeling step,

whereby the method is characterized by comprising the following formula to calculate the respective next value of the entry control quantities:

$$x'_{n+1} = \frac{v_n}{1+\rho_n(1-v_n)} \qquad (6a)$$

where ρ_n is a suitable parameter and

$$v_n = (n+1)u - nu_n \qquad (6b)$$

χ'_n is valid for the next iteration only ~~while μ_n~~ while u_n and ρ_n are values measured from the beginning of the simulation.

Please replace paragraph [0031] with the following amended paragraph:

[0031] Total run ~~time τ~~ time T is the sum of system idle ~~time ι~~ time I, *instruction* processing time P and system wait time W:

$$T = I + P + W. \qquad (1)$$

During P, the system is assumed to process instructions at infinite cache speed. W is the total time a CP is delayed waiting for a storage hierarchy (SH) request to be resolved. Then, total CP utilization at ~~time τ~~ time T is

$$u_T = (P + W)/T, \qquad (2)$$

and the "entry control quantity", i.e., the CP's entry utilization - i.e., its relative utilization during P - becomes

$$x_T = P/(P + I). \qquad (3)$$

Please replace paragraph [0033] with the following amended paragraph:

[0033] Where ~~$\rho\tau=W/P$~~ $\underline{\rho_T=W/P}$, or equivalently

$$x_T = \frac{u_T}{1+\rho_T(1-u_T)} \,. \qquad (5)$$

Please replace paragraph [0035] with the following amended paragraph:

[0035] In the following formulas,
~~μ denotes~~ $\underline{u}$ denotes the *target utilization* finally aimed at,
$\Delta_n=[T_{n-1},T_n]$, with $T_n=n\Delta$ is the *n*-th interval of observation time,
I'_n, P'_n and W'_n denote the idle, processing and wait time within Δ_n,
I_n, P_n and W_n the respective accumulative times up to T_n,
~~μ'_n and~~ $\underline{u'_n}$ and χ'_n denote the instantaneous total and entry utilization within Δ_n, and
~~μ_n and~~ $\underline{u_n}$ and χ_n the respective accumulative utilizations up to T_n.

Please replace paragraph [0036] with the following amended paragraph:

[0036] Relying on formula (5), all information available at ~~time τ_n~~ time $\underline{T_n}$ is used to choose the next value for the entry utilization. Thus, the inventive key regulation formula reads:

$$x'_{n+1} = \frac{v_n}{1+\rho_n(1-v_n)} \qquad (6a)$$

where $\rho_n = W_n / P_n$ and

$$v_n = (n+1)u - nu_n \qquad (6b)$$

Please replace paragraph [0037] with the following amended paragraph:

[0037] Since ~~μ_n aims to approach μ~~ u_n aims to approach u, the simple choice

$$x'_{n+1} = \frac{u}{1+\rho_n(1-u)} \qquad (7)$$

also makes CP utilization converge ~~against μ~~ against u - slower, however, than with formula (6a, 6b).

Please replace paragraph [0039] with the following amended paragraph:

[0039] Assuming $W_1 = P_1$ or $\rho_1 = 1$, the iteration starts with the entry utilization ~~$\chi'_1 = \chi_1 = \mu/(2-\mu)$, where μ~~ $\chi'_1 = \chi_1 = u/(2-u)$, where u is the target utilization.

Please replace paragraph [0042] with the following amended paragraph:

[0042] From (2), ~~$\mu_1=(P_1+W_1)/T_1$~~ $\underline{u_1=(P_1+W_1)/T_1}$ is calculated, and formula (6) is applied to arrive at the entry utilization χ'_2 to be used in $\Delta_2=[T_1,T_2]$.

Please replace paragraph [0044] with the following amended paragraph:

[0044] Then from (2), ~~$\mu_2=(P_2+W_2)/T_2$~~ $\underline{u_2=(P_2+W_2)/T_2}$ is calculated and the procedure can be iterated as often as required by any finish-criterion.

Please replace paragraph [0047] with the following amended paragraph:

[0047] Since obviously

$$u_n' = nu_n - (n-1)u_{n-1} \qquad (9)$$

(8) turns into (6), ~~if μ_{n+1}~~ <u>if u_{n+1}</u> is assumed to be sufficiently close ~~to μ~~ <u>to u</u> and hence ρ'_{n+1} close to ρ_n.

Please replace paragraph [0049] with the following amended paragraph:

[0049] This is equivalent to the iterative formula

$$x_{n+1} = \frac{x_n}{1+d_n(1+\rho_n x_n)} \qquad (11)$$

where ~~$d_n=(\mu_n-\mu)/\mu$~~ $\underline{d_n=(u_n-u)/u}$.

Please replace paragraph [0050] with the following amended paragraph:

[0050] From (11), it follows that $\chi_{n+1}\leq\chi_n$ and hence ~~$\mu_{n+1}\leq\mu_n$ if $\mu_n\geq\mu$~~ $\underline{u_{n+1}\leq u_n \text{ if } u_n\geq u}$ and vice versa. This guarantees ~~that $\{\mu_n\}$~~ <u>that $\{u_n\}$</u> in fact converges against the target CP ~~utilization μ~~ <u>utilization u</u> or at least oscillates sufficiently close ~~around μ~~ <u>around u</u>.

Please replace paragraph [0058] with the following amended paragraph:

[0058] Thus, the working units' throughput is the target control ~~quantity μ~~ <u>quantity u</u> in the sense of the appended claims. The throughput is synonymously denoted with a more generalized term of 'utilization' of the working unit 10. The load imposed by the driver unit is the working unit's entry utilization χ'.

Please replace paragraph [0059] with the following amended paragraph:

[0059] According to the generalized approach, a utilization measurement facility 20 measures the actual ~~utilization μ_n~~ utilization u_n of the working unit 10 by means of a predetermined scanning scheme and reports the measured utilization values to a control element 22. Measurement and report frequency may vary according to any physical requirements present in the respective application case.

Please replace paragraph [0060] with the following amended paragraph:

[0060] The control element 22 stores a predetermined value of target ~~utilization μ~~ utilization u associated with the working unit 10. The control element 22 processes the measured actual ~~utilization μ_n~~ utilization u_n by means of the inventive formula (6a, 6b) and calculates a new entry utilization χ'_{n+1} which the driver unit 12 uses to drive the working unit 10 until the next utilization measurement is performed. Thus, a closed loop control is implemented, involving the inventive formula.

Please replace paragraph [0066] with the following amended paragraph:

[0066] According to the preferred embodiment given in here, the time each processor 32 spends waiting for a request to ~~complete μT~~ complete is recorded in a table. Together with the processor's entry utilization, this wait time determines the actual ~~load~~ load u_T of each processor 32 at any time T. As

detailed above, an accurate simulation of the CP utilization is key for a high quality performance model.

Please replace paragraph [0069] with the following amended paragraph:

[0069] With regard to the target ~~utilization μ~~ utilization u, a first entry utilization χ'_1 is selected in a plausible way. From χ'_1 and from the request rates read-in before, the mean time $\tau=\tau_1$ between any two requests is determined. Said mean time is referred to herein as interarrival time.

Please replace paragraph [0072] with the following amended paragraph:

[0072] Upon each call, said statistics routine calculates the actual total ~~utilization μ_n~~ utilization u_n of the processors 32 from their entry utilization χ'_n and the table-stored request wait time as described above in the introductive theoretical section. The initialization routine in turn uses the inventive formula (6a, 6b) to calculate the entry utilization χ'_{n+1} for the next observation period from ~~μ_n and μ~~ u_n and u. Finally, ~~from the $\tau=\tau_{n+1}$ new value~~ from the new value of the entry utilization, the mean interarrival ~~time is~~ time $\tau=\tau_{n+1}$ is re-calculated and used from now on by the processing units 32.

Please replace paragraph [0076] with the following amended paragraph:

[0076] Better convergence is achieved with further approaches depicted by the graphs with reference signs 52 and 53: Instead of the fixed value *d* used in method 51, they use the actual deviation from target utilization ~~$d_n=(\mu_n-\mu)/\mu$~~ $\underline{d_n=(u_n-u)/u}$ to adjust entry utilization. Two approaches are shown herein.

Please replace the abstract with the following amended abstract:

Feedback control algorithms for controlling a given simulation model which relates to a computer-program-based method and respective system for providing a feedback control for a given set of control quantities of a simulation model, comprising a plurality of iterated simulation runs each of which consumes a considerable amount of time. Each single run is performed with a setting of starting values for certain entry control quantities suited to control certain target quantities. The respective next setting of entry quantities is based on the value of the target quantities measured in the preceding simulation run. In order to provide for a fast convergence of the target quantities to a final, predetermined value, the following formula is applied:

$$x'_{n+1}=\frac{v_n}{1+\rho_n(1-v_n)} \qquad \cancel{(6a)}$$

where

$$v_n=(n+1)u-nu_n \qquad \cancel{(6b)}$$

~~μ is~~ <u>u is</u> the final value of the target control quantity aimed ~~at, $\mu\mu_n$~~ <u>at u_n,</u> its value achieved up to iteration n of the simulation run and ρ_n is a suitable system parameter. χ is a

certain entry quantity suited to make ~~μ_n converge against μ~~ u_n converge against u, and χ'_{n+1} is the value of χ to be chosen for the next iteration.